



Outlines:

Model for adiabatic stability calculation

- basic description;
- current and field distributions;
- critical current parameterization;
- energy depositions due to flux change;
- strand enthalpy;
- adiabatic stability criterion;

Results of calculation

- strand parameters;
- critical currents;
- effective filament sizes;

Conclusion



Model description

$B(B_{ext}, T, I, X)$



$\Delta W(B_{ext}, T, \Delta T, I)$



$\Delta Q(T, \Delta T)$



$\Delta W(B_{ext}, T, \Delta T, I) > \Delta Q(T, \Delta T)$



$\Delta T_s(\Delta W = \Delta Q)$



$\Delta W(B_{ext}, T, \Delta T_s, I) > \Delta Q(T, \Delta T_s)$

- field distribution inside a filament;

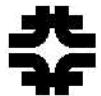
- energy increment due to a temperature variation;

- strand enthalpy due to a temperature variation;

- determining if there is an instability;

- determining temperature increment of stable equilibrium;

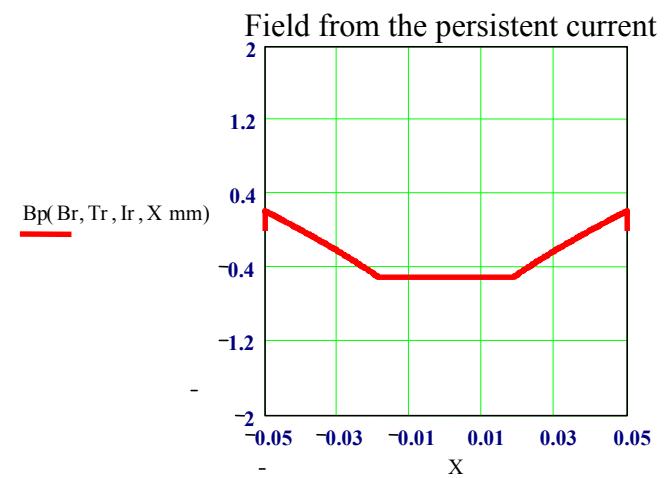
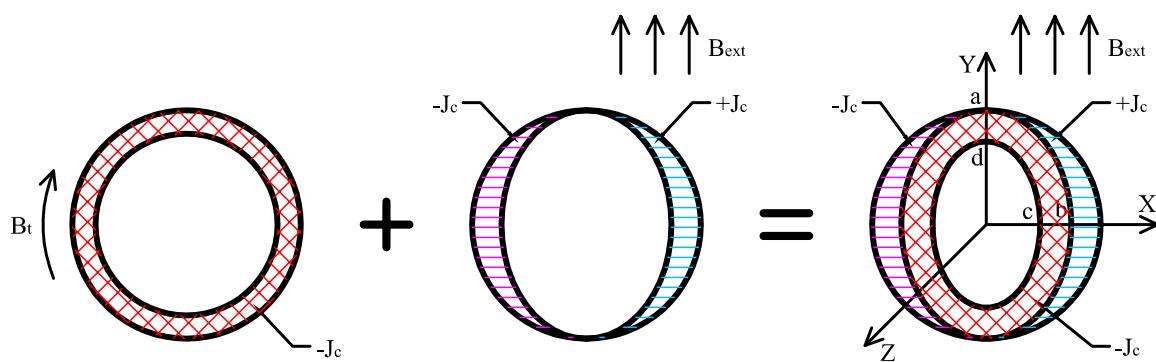
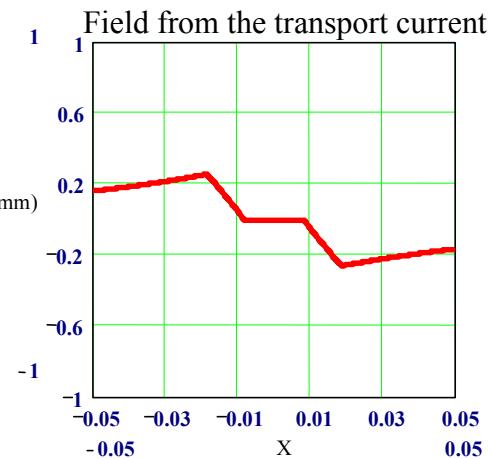
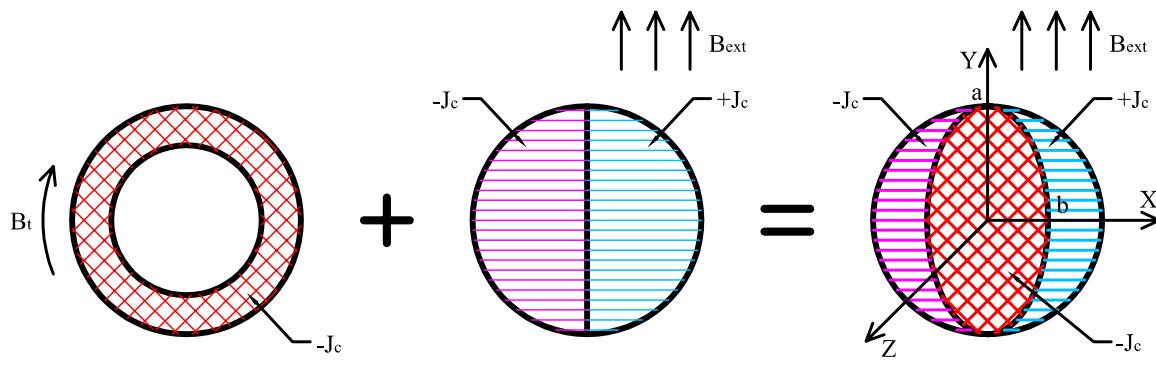
- determining if instability causes transition to normal state;

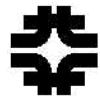


Fermilab

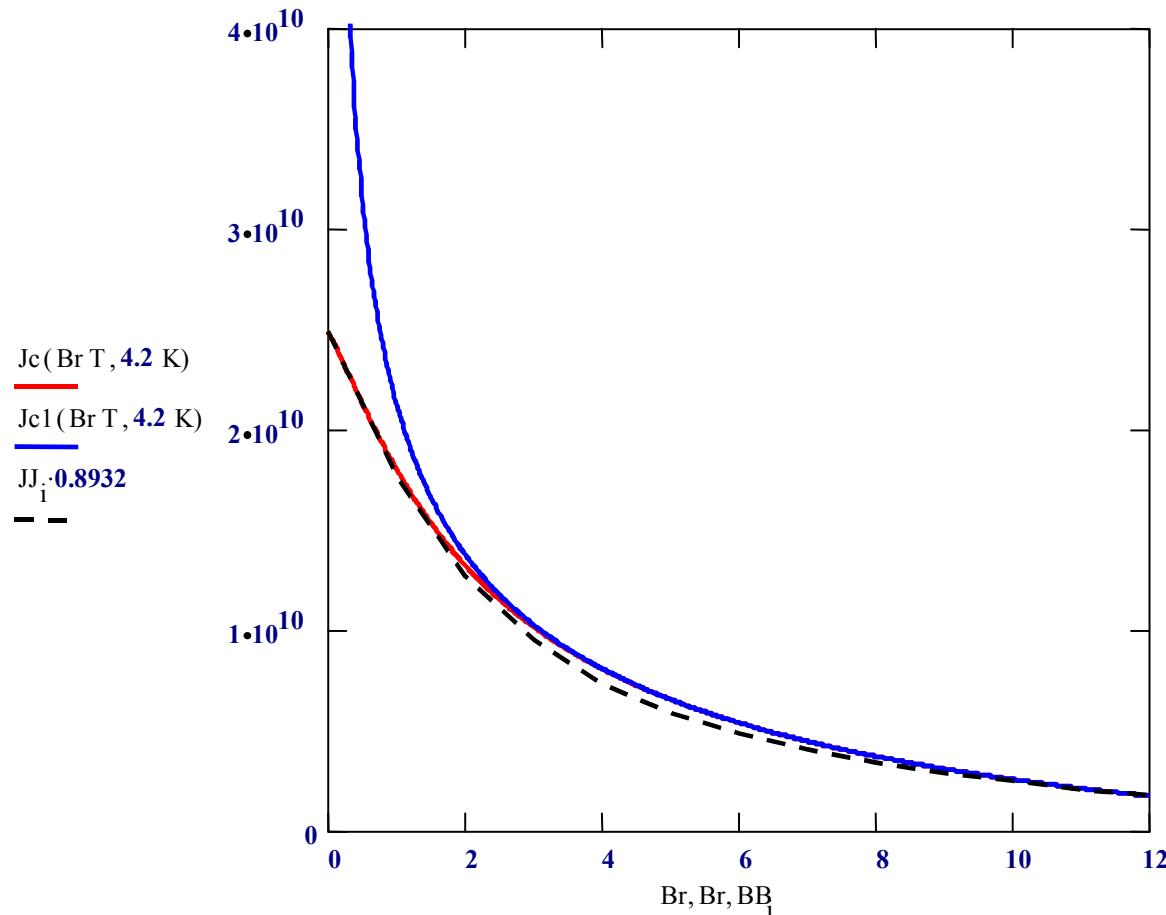
Strand stability calculations

Field in a filament (Bean's model)

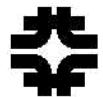




Parameterization of critical current



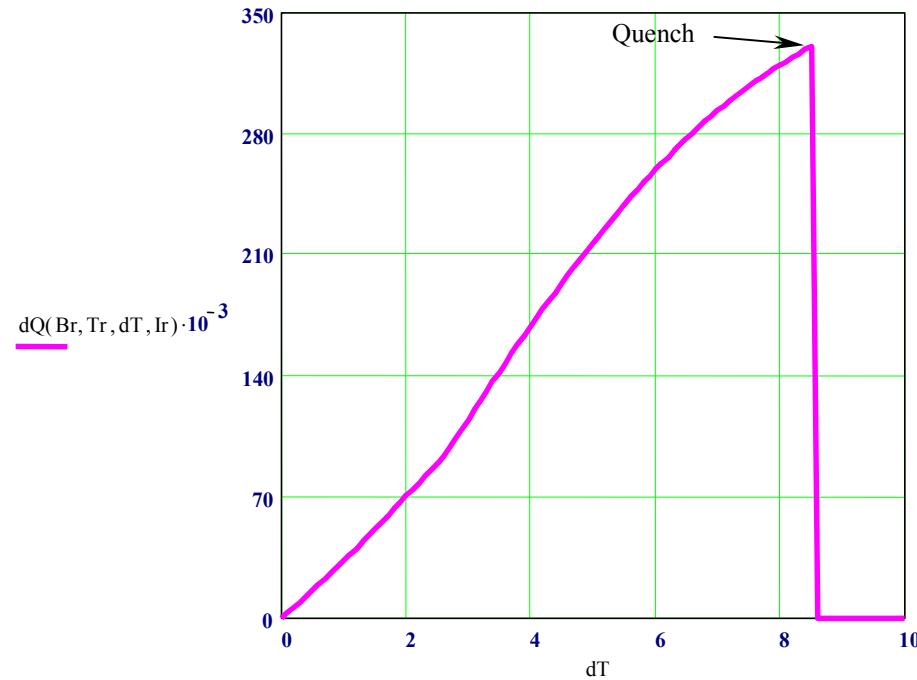
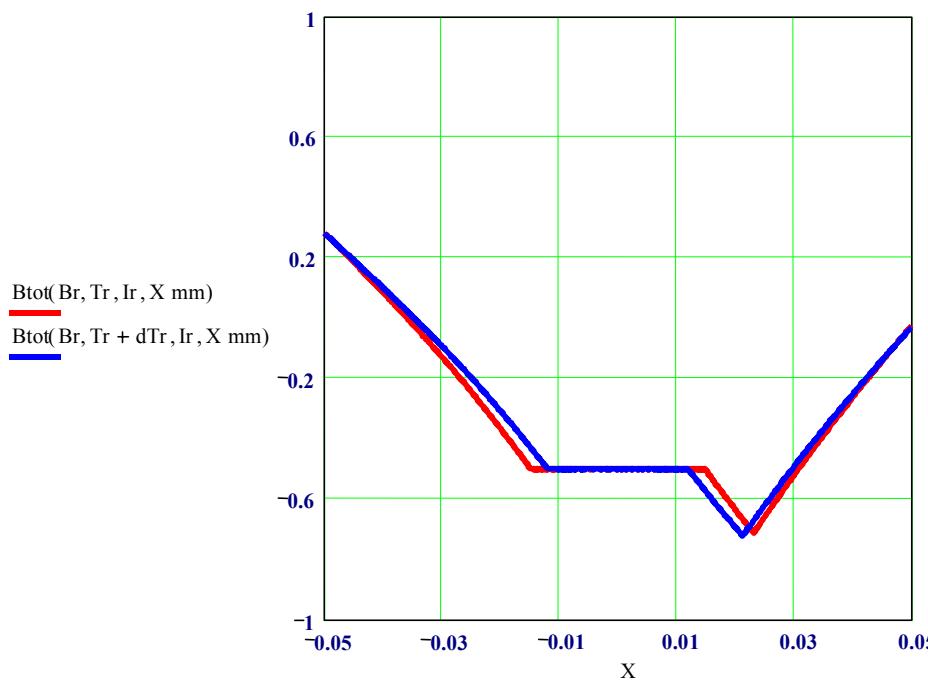
Summers parameterization
corrected at low fields to match
magnetization measurements

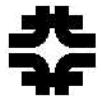


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Strand stability calculations

Energy deposition due to a temperature change

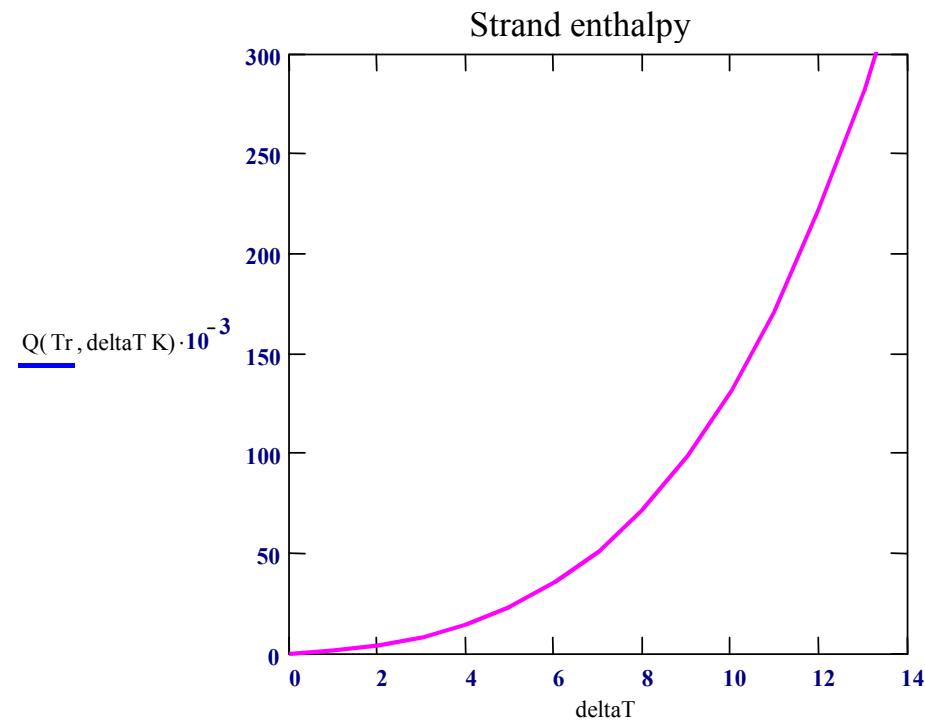
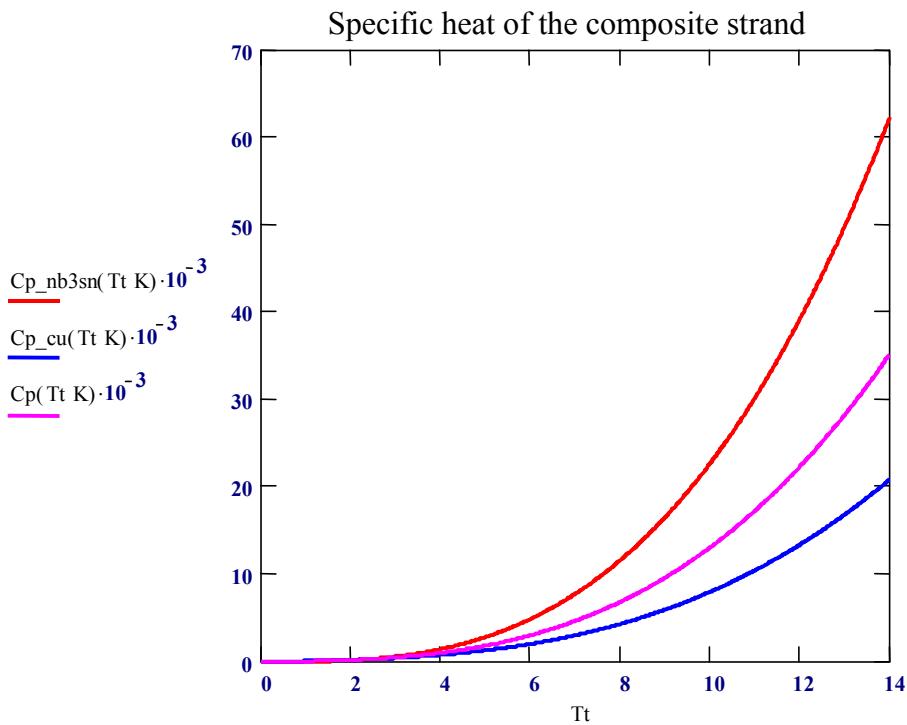


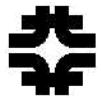


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Strand stability calculations

Strand specific heat and enthalpy



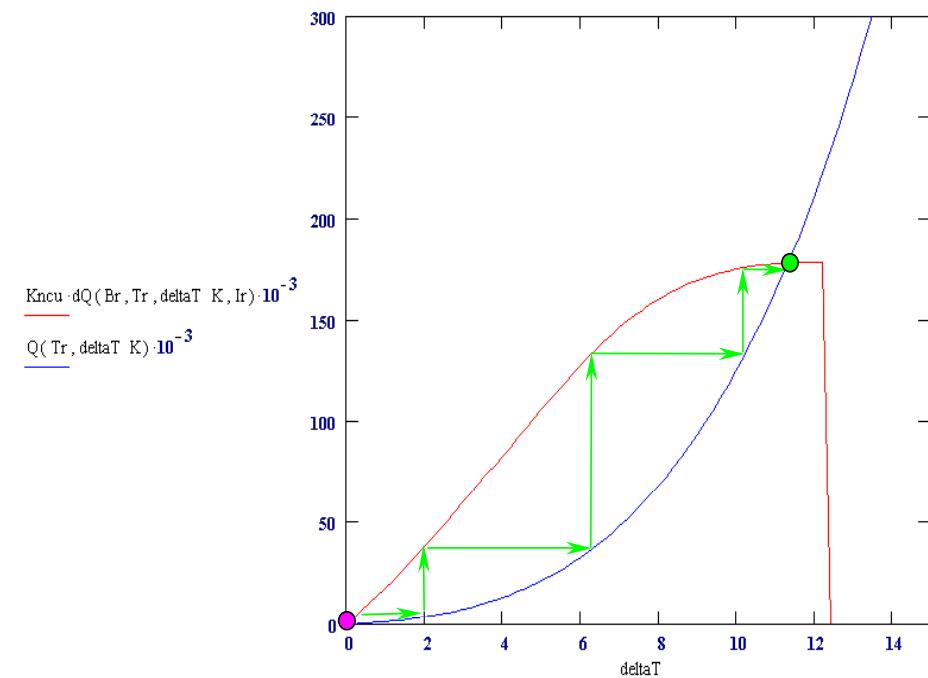


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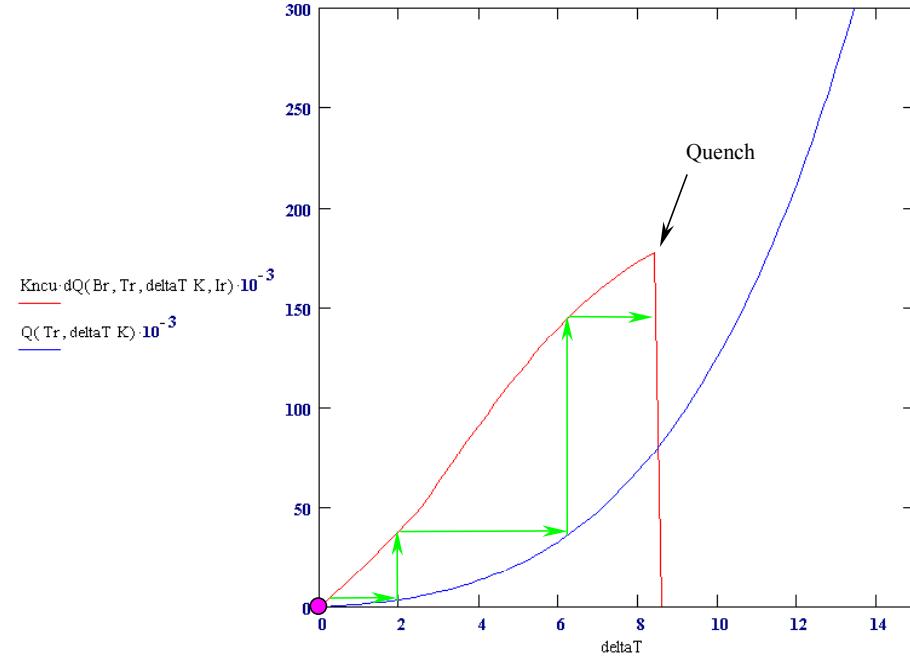
Strand stability calculations

Adiabatic stability criterion

Stability reached
before quench



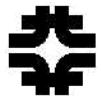
Quench happens before
stability is reached





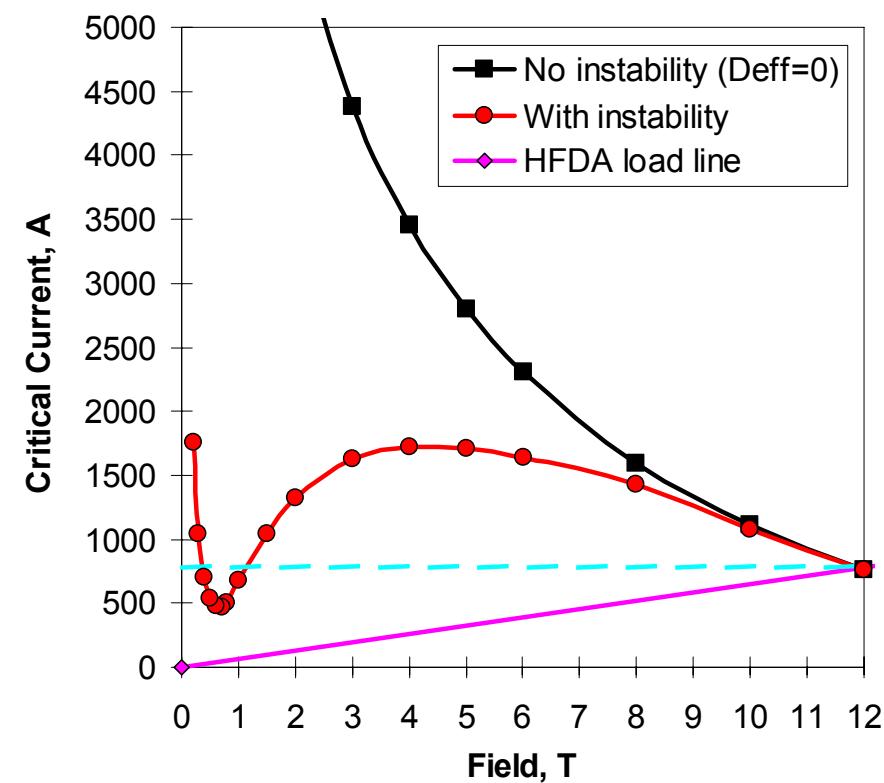
Parameters of MJR strands used at Fermilab

Parameter	Unit	Racetrack magnet	Shell magnet
Strand diameter	mm	0.7	1.0
Effective filament diameter	µm	78	110
Cu to non-Cu ratio		0.85	0.85
Nb ₃ Sn fraction in the non-Cu		0.64	0.64
Reference critical current	A/mm ²	1786.4	1786.4
Reference field	T	12	12
Reference temperature	K	4.2	4.2
Upper critical field	T	28	28
Upper critical temperature	K	18	18

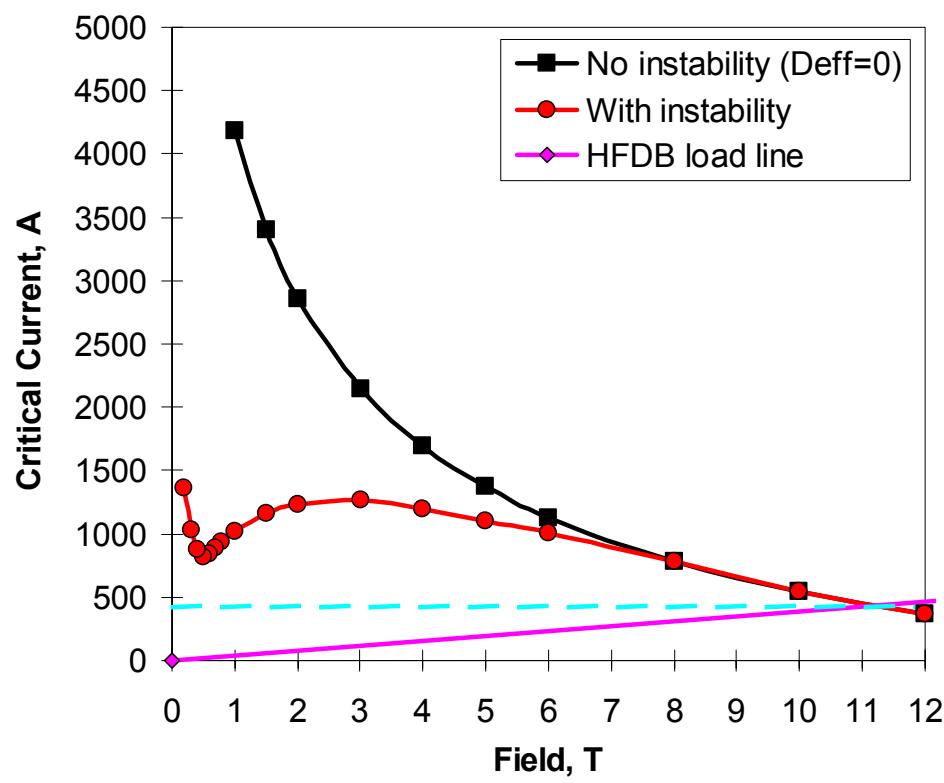


Critical current with instabilities

1-mm strand



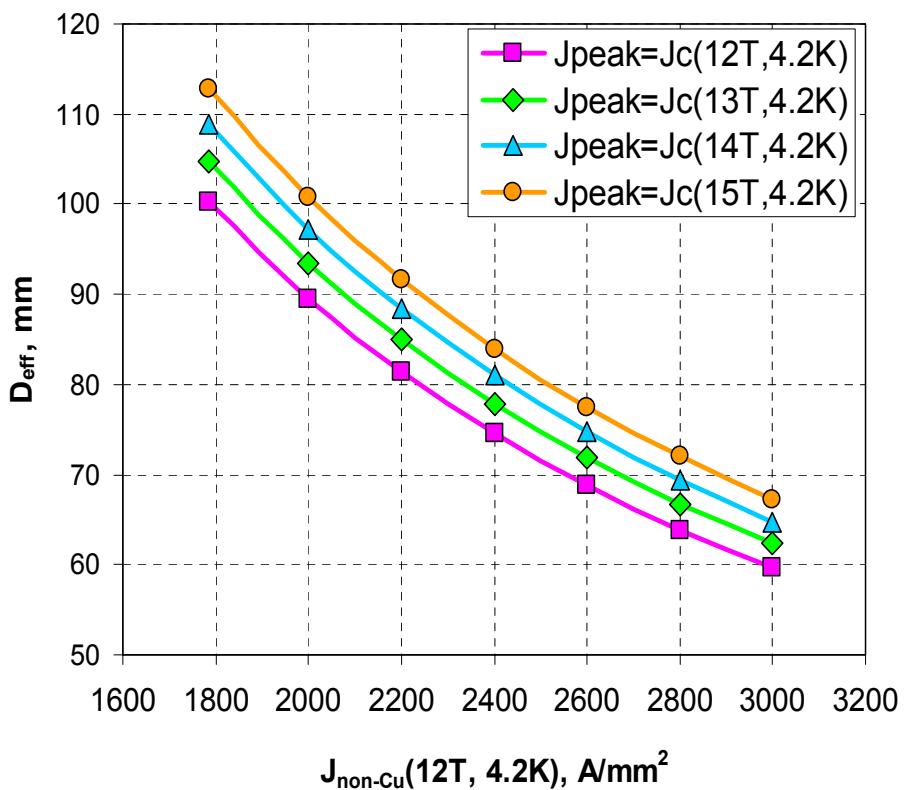
0.7-mm strand



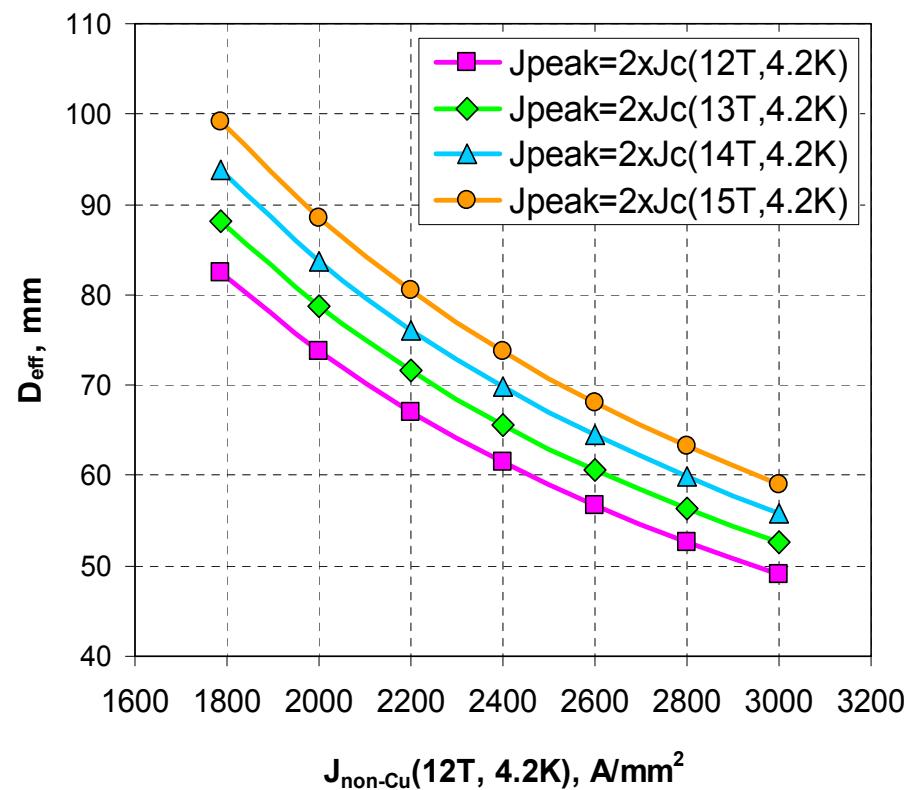


Stable filament size

No margin



100% margin





Conclusion

A model for the analysis of adiabatic instabilities in superconducting strands was built and tested with two strand types used in Fermilab cosine-theta and racetrack magnets. It was found that calculated quench current has a good correlation with the one measured in the cosine-theta short models. The model suggests that the reason of premature quenches in the racetrack models is not in the magnetic instabilities alone.

More work needs to be done on verifying the model with the strand measurements and analyzing effects of non-uniform transport current distribution within a strand, heat transfer and current sharing between adjacent filaments and external cooling by liquid helium.